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(71)(72) Applicant and Inventor: TAYLOR, John, Brengle [NZ/NZ]; 10 Maryhill Avenue, Hoon Hay, Christchurch 8002 (NZ).

(74) Agents: LYTH, Richard, John et al.; Baldwin Son & Carey, 342 Lambton Quay, Wellington 6001 (NZ).

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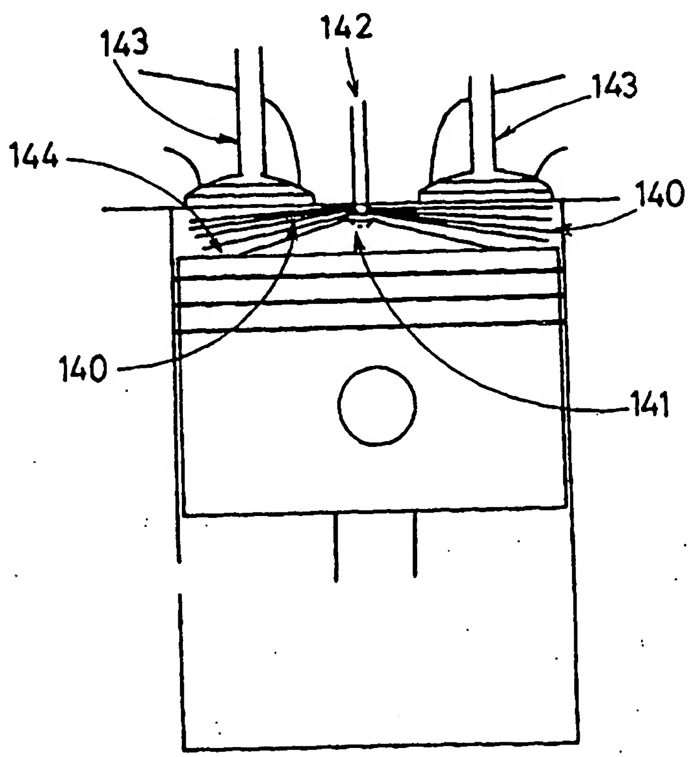
(57) Abstract

Inlet and exhaust valve timing is varied in conjunction with reducing the engines compression ratio and increasing drive to the supercharger. Variations include the early opening of one or more exhaust valves and/or closure of one or more inlet valves and/or late closure of one or more inlet valves and/or the closure of one or more inlet valves prior to the end of each induction stroke. Such variations may be implemented using a variable compound timing wheel for a valve operating camshaft wherein the variable timing wheel is particularly adapted to advance or retard valve operation in response to electronic or hydraulic actuation means. The invention further provides for an improved piston for a compression ignition engine particularly adapted so that upon fuel injection and subsequent compression of the air/fuel mixture, the mixture is forced radially outward from the axis of the piston. The piston has a conical upper surface extending radially to the edge of the top surface or partially outwards to the edge of the top surface.



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IMPROVEMENTS TO ENGINES

The present invention relates to engines and methods of operating engines. More particularly, although not exclusively, the present invention relates to modifications in the construction and operation of internal combustion engines.

Background To The Invention

To the present time numerous techniques have been proposed to enhance the efficiency or otherwise modify the characteristics of an engine to achieve a particular effect. Such effects include the reduction in pollutants exhausted from engines and increased fuel efficiencies. Techniques in the prior art have met with mixed success and alternative methods and constructions are provided herein in order to enhance the efficiency and power characteristics of said engines, or to at least provide the public with a useful choice.

Reference is made to a reciprocating piston type internal combustion engine of the type described in patent specification No. PCT/NZ94/00109 the disclosure of which is herein incorporated by reference.

Further objects and advantages of the present invention will become apparent from the following description which is given by way of example only.

Disclosure Of The Invention

According to the invention, there is provided a reciprocating piston type internal combustion engine including supercharging and turbocharging means, the engine being adapted so as to reduce its compression ratio and increase drive to the supercharger.

Preferably the reduction in compression ratio in each cylinder is effected by varying the timing of one or more inlet valves, more preferably by closing the one or more inlet valves prior to the end of the induction stroke of the cylinder.

In a further embodiment, the present invention provides for a reciprocating piston type internal combustion engine incorporating boosted induction.

Preferably the boosted induction is effected by means of supercharging and/or turbocharging means.

In a further embodiment, the present invention provides for a method of varying valve timing in a reciprocating piston type internal combustion engine including:

early opening of one or more exhaust valves and/or late closure of one or more inlet valves and/or the closure of one or more inlet valves prior to the end of each induction stroke.

Preferably the closure of the one or more inlet valves prior to the end of the induction stroke occurs in conjunction with a reduction in compression ratio of the engine and/or in conjunction with boosted induction.

Preferably the method of varying valve timing further comprises:

closing one or more inlet valves substantially at bottom dead centre of piston travel on crankshaft rotation.

Preferably the closure of the one or more inlet valves occurs up to 15 degrees of crank rotation after bottom dead centre, more preferably at or before bottom dead centre.

Preferably the inlet and exhaust valves action have little or no overlap, more preferably the exhaust valve opens at approximately 50 degrees before bottom dead centre.

Preferably the method of varying valve timing further comprises:
delaying the closure of the one or more inlet valves until after the compression stroke has started.

Preferably delaying of the closure of the one or more inlet valves after the compression stroke starts at higher engine speeds.

In a further aspect the present invention provides for a variable timing wheel for a valve operating camshaft wherein the camshaft is driven by a variable timing, compound wheel.

Preferably the compound wheel comprises:
a hub section located on or in association with the axis of a camshaft;
a rotational drive means capable of transmitting rotational movement to the hub section about it's axis;
a first actuation means, wherein the hub section, drive means and first actuation means are coaxial and are adapted so that when the first actuation means is displaced along the axis, the hub section and rotational drive means rotate relative to one another around their common axis.

Preferably the hub section comprises a drive shaft which protrudes from the axis of the camshaft and has a male meshing means adapted to mesh with a complementary

female meshing means in the first actuation means, and where the rotational drive means comprises a drive wheel adapted to mesh with the exterior of the first actuation means wherein when the first actuation means is axially displaced the hub section and the rotational drive means are to rotationally displaced with respect to one another.

In an alternative embodiment, the camshaft has a female meshing means adapted to mesh with a male meshing means in the first actuation means.

Preferably the meshing means comprise angled splines or slots which react and mesh with pins or recesses.

Preferably the first actuation means is displaced axially by hydraulic, electronic or mechanical means.

Preferably the first actuation means comprises a cylindrical body which incorporates meshing means on its outer surface and a female axial meshing recess at one or both ends.

Preferably the rotational drive means is constrained so as not to be capable of axial movement.

Preferably the first actuation means is controlled by an engine management system, a speed and/or load sensitive governor or directly by an operator.

In a further embodiment the present invention provides for a piston for a compression ignition engine comprising:

a cylindrical member having a central axis and a top surface or crown comprising a convex surface which is adapted so that upon fuel injection and subsequent compression of an air/fuel mixture, the air/fuel mixture is forced radially outward from the axis of the cylindrical member.

Preferably the top surface comprises a substantially convex conical surface which is symmetrical about the axis of the cylindrical member and where the conical shape extends radially to the edge of the top surface.

Preferably the substantially convex conical surface extends outwards so that a substantially flat annular portion is formed in the top surface between the edge of the convex conical surface and the edge of the cylinder.

Preferably the piston and/or cylinder may be used in conjunction with boosted induction.

Preferably the piston moves in a cylinder which is adapted so that at the top of the compression stroke, the space between the cylinder head and the substantially flat annular surface surrounding the convex surface is of negligible volume, thereby expelling substantially all of the air between the aforesaid surfaces at the top of the compression stroke.

Preferably the piston and/or cylinder head in which the space between the cylinder head and the substantially flat annular surface is of negligible volume may be used in conjunction with low boosted induction or no boosted induction.

Preferably the piston and/or cylinder head is used in conjunction with the valve timing method above.

Preferably the valve timing is implemented by means of the variable timing wheel described above.

Brief Description Of The Drawings

The invention will now be described by way of example only and with reference to the figures in which:

Figure 1	Illustrates an exploded view of a compound timing wheel construction;
Figure 2, a, b, c	Illustrates a selection of piston crown profiles;
Figure 3	Illustrates a perspective view of a piston crown;
Figure 4	Illustrates a side view of a piston crown incorporating valve cutaways;
Figure 5	Illustrates a cross-sectional view of an articulated two piece piston;
Figure 6	Illustrates a cross-sectional view of a piston;
Figure 7	Illustrates a cross-sectional view of a piston;
Figure 8	Illustrates a side view of a prototype piston;
Figure 9	Illustrates a cross-sectional view of a piston;
Figure 10 a, b, c	Illustrates cycle diagrams for starting, low speed and high speed engine operation;
Figure 11 a, b	Illustrates cycle diagrams for variable inlet valve opening;
Figure 12 a, b	Illustrates cycle diagrams for variable exhaust valve openings; and
Figure 13	Illustrates a modified cylinder head and piston.
Figure 14	Illustrates a cross section view of a modified piston in operation.

In the accompanying Figures 10a-c to 12a-b, the valve movement is indicated by the arrow at the top of the cylinder. Valve closure is denoted by an arrow pointing to the valve and valve opening is denoted by an arrow pointing away from the valve.

The present invention is generally concerned with methods and apparatus for varying the timing of valve opening and closure in internal combustion engines as well as cylinders for use in same. Such techniques have been examined in conjunction with modifications incorporating supercharging and turbocharging. A number of techniques will be discussed herein in the context of a reciprocating piston type internal combustion engine of the type described in patent specification No. PCT/NZ94/00109 in a variety of operating regimes.

An engine of the type described in patent specification No. PCT/NZ94/00109 was modified by incorporating a supercharging unit and turbocharging unit. The engine was further modified so as to reduce it's compression ratio while increasing it's drive to the supercharger. It has been found that an engine incorporating these modifications has significantly improved fuel efficiency.

By providing for a low compression ratio which is compensated with a heavily supercharged intake charge, more air will be available for the combustion of fuel and the combustion will be more efficient. Also, peak cycle temperatures will be lower and by providing air in excess of that required for combustion, the peak cycle pressures will be lower. In such an operating regime, the emission of CO, hydrocarbons and NOx will be reduced.

In the cycle diagrams shown in figures 10, 11 and 12 the inlet valve is located on the left of the cylinder head and the exhaust valve at the right of the cylinder head.

Referring to figure 10b the turbocharger and supercharger were arranged in series and the inlet valve was closed slightly before the piston of each cylinder ended it's induction stroke. In the context of a compression ignition engine (ie; diesel), it may be desirable to reduce the cylinder compression ratio to below that at which compression ignition occurs and compensate for the reduction in compression by supplying the cylinder with pre-compressed air from the supercharger. Such a configuration could utilise a supercharger being powered by the engine.

In experimental trials, the applicant used a supercharged turbo powered diesel engine incorporating reduced valve overlap. The standard compression ratio of 16:1 was reduced to approximately 13.5:1. The drive to the supercharger was modified to increase power thereto. The valve overlap was 50 degrees compared with 100 degrees overlap as illustrated in figure 7 of patent specification No. PCT/NZ94/00109. The inlet valve was set to close slightly before bottom dead centre (BDC).

In it's standard configuration the power output of the engine was determined to be 91.5 brake horse power (bhp). With the modifications outlined above, the power output was 125 bhp. In the modified configuration, the measured exhaust emission of, for example, nitrous oxide was reduced and the invention provided enhanced fuel efficiency and smooth running characteristics.

In an alternative configuration, the engine was modified to include a supercharger and/or a turbocharger. The purpose of such 'boosted induction' is to provide additional

work on a piston by super-boosting the intake air or the intake charge which forces the piston down on a work cycle while simultaneously supplying a cylinder with a fresh air or intake charge prior to the compression stroke and fuel ignition. In an example, the super-boosted air could have a pressure of approximately 20 psi or similar so as to provide effective work on a piston during the induction cycle, thereby adding to the engines output work.

The intake of super-boosted air is controlled by inlet valve timing. This is to avoid over-boosting the cylinder. The inlet valve in this example, is closed approximately near BDC of piston travel on crankshaft rotation as shown in figure 11a. Depending on the engine load this could occur up to 15 degrees of crank rotation after BDC, but more preferably will be at BDC or before BDC. In comparison, in conventionally boosted engines, valve closure occurs at around 50 degrees after BDC, ie; when the piston is rising on compression. Closing the inlet valves earlier than normal moderates the boost back to lower boost levels for the compression cycle thereby reducing negative work on the piston, while allowing super boost pressures to add work, via a piston on the early stages of the induction cycle, to the engine crankshaft thereby increasing the engines output. The exhaust and inlet valves have little or no overlapping action with the exhaust valve being opened at approximately 50 degrees before BDC in order to drive the turbocharger sufficiently to effect super-boosting. The boosted induction for this engine configuration could be implemented using high energy exhaust gasses. It has been found that such modifications can increase the output by up to 35% per unit fuel volume.

Alternative valve timing methods have been analysed to determine their effect on engine efficiency and exhaust pollutant content. To this end, the applicant has found that

if the exhaust valves are opened earlier than normal, the compression charge temperature will be reduced. Such an operating regime is illustrated in figures 12a and 12b. For partial load and low turbo boost, the exhaust valve is opened towards the end of the power stroke as shown in figure 12a. For full load heavy turbo boost, the exhaust valve can open early in the power stroke as shown in figure 12b. Analysis of exhaust gasses in this operating regime revealed a reduction in NOx content, the effect being particularly apparent at low engine speeds. It is presumed that the lower compression charge temperature is the result of a cooler cylinder. This results from the high temperature and high pressure exhaust gasses spending less time in the cylinder and being expelled before the piston completes it's power stroke.

In this operating regime, the exhaust valves are opened shortly after the piston has reached maximum velocity on the power stroke. This could occur at 90 crankshaft degrees before the end of the piston travel on the power stroke, or alternatively approximately 40 to 90 crankshaft degrees before the end of the piston travel on the power stroke. The selection of a particular timing for a valve would depend on whether the engine had a high or low pressure power stroke.

Some of the power stroke energy which is lost could be recovered by incorporating a turbocharger and using high boost pressure to cause the induction stroke to be a secondary power stroke and controlling the boost pressure as described herein so as to avoid excessively high compression pressures.

At high engine speeds, ultra-early exhaust valve opening may not be required. This could be achieved by retarding the appropriate camshaft rotation proportionally with the engine speed . Alternatively or in combination with the above technique, the

camshaft which operates the exhaust valves may be advanced for heavy engine loads, and retarded for lighter engine loads.

A further variation on valve timing is shown in figure 10c and includes the operating regime whereby the inlet valve closure is delayed until after the piston starts it's return movement (ie; on the compression stroke). This may be particularly appropriate at higher engine speeds to effect efficient filling of the cylinder. In accordance with the present invention, this may be effected by varying the operational timing of the at least some of the inlet valves, by means of the camshaft, in proportion to the engine speed or load. This may be achieved by using one or more camshafts whereby selected valves may be operated by a one camshaft with the remainder being operated by one or more crankshafts.

Referring to figure 10a, at starting speed for a diesel engine the camshaft will retard its operation and delay the closure of one of more inlet valves until after the piston starts it's return movement following the induction stroke. This will enhance starting compression. This procedure may not be required for a spark ignition engine. Once the compression ignition engine has started and attained a normal operating temperature, the camshaft will automatically advance so as to close one or more inlet valves before the end of the piston induction stroke at low engine speed as shown in figure 10b. The camshaft will automatically retard it's action in relation to the crankshaft movement as engine speed rises (see figure 10c). This will result in the closure of the one or more inlet valves being delayed as the engine speed rises. This closure delay will be in proportion to the engine speed. This will aid in cylinder filling with intake charge at higher engine speeds. An effective method of controlling the camshaft in the desired manner is by means of a compound wheel as described below.

The present invention further provides an apparatus for implementing the variable valve timing as discussed above. A camshaft may be driven by a variable timing, compound wheel. An example of such a compound wheel is shown in figure 1. Referring to figure 1, a camshaft 4 has a hub section 5 attached to one end. A rotational drive wheel 3, actuation means 1 and 2, camshaft 4 and the hub section 5 are all coaxial. The rotational drive wheel 3 is constrained axially. The actuation means is shown as two distinct components, however, they may be integrally constructed. The hub section 5 is meshed by way of angled splines 6, with a complementary female recess (not shown) in the actuation means 2. The rotational drive means 3 is meshed by way of angled spline recesses 7, with angled splines 8 on the outside surface of the actuation means 2. It is to be understood that the location of the female and male meshing means may be reversed. Such a modification being within the scope of the present invention. The actuation means 2 is capable of axial movement. If the arrangement is considered when stationary, it can be seen that if the actuation means 2 is moved axially towards rotational drive means 3, meshing will cause the rotational drive means to rotate. Simultaneously with the axial movement of the actuation means 2 towards the rotational drive means 3, the meshing between the hub section 5 and the female recess in the actuation means 2 will cause the camshaft to rotate. Depending on the orientation of the angled splines, the movement of the actuation means 2 will result in relative rotational displacement of the rotational drive means 3 and the crankshaft 4, thus retardation or advancement of the camshaft may be effected.

The actuation means 2 may be controlled by hydraulic, electronic or similar means which are known in the art. Such control may also be effected by automatic engine control means or by an operator. The rotational drive means 3 is axially constrained thus the separation between the hub section 5 and the rotational drive means

3 is constant, and the rotation of the drive means 3 is thereby transmitted to the camshaft by way of the hub section 5 while their respective rotational displacements may be varied according to the position of the actuation means 2.

The compound wheel described above is particularly suitable for use with one or more camshafts, configured to provide for the particular valve timing variation desired. It is to be appreciated that one or more camshaft may be fitted to an engine whereby each camshaft operates selected valves and incorporates a compound wheel in accordance with the invention.

The invention further provides for a modified piston head examples of which are shown in figures 2, 6, 7, 9 and 14. These piston designs may find particular application in the modified operating regimes described above. As shown in figure 3, an example of a piston has an upper surface shaped as a convex conical surface of revolution (about the axis of the cylinder). In the example shown in figures 2c and 6, a piston is shown with an upper surface in the shape of a cone extending completely to the edge of the piston. Referring to figure 5, 6 and 7 this piston may include a small hollowed area 50, 60 and 70 respectively adapted to accommodate the injector when the piston is at the end of it's travel. Figure 2b illustrates a further embodiment whereby the piston crown incorporates a hollowed out swirl area 20. In all cases the top centre of the pistons is substantially higher than the edges.

In operation, the conical surface shape pushes the air out radially into the fuel spray. This improves mixing of the fuel and air and exposes burning gases to cooler parts of the engine thereby reducing the rate of NOx formation. Further improvements

can be observed when the novel cylinders are used in conjunction with the boosted induction technique discussed above.

Similarly, in figure 2a, 3 and 7 a piston is shown having a raised upper surface 21 having a conical shape and having an annular substantially flat landing for the swirl area. The embodiment in figure 7 also incorporates the hollowed recess 70 to allow clearance for the fuel injector. A further variation in this piston design incorporates valve cutaways as shown in figure 4.

The pistons described in the present specification all incorporate a centre section that is raised substantially above the edges of the piston. This results in the combustion chamber being formed between the piston, the cylinder head and the cylinder walls. The effect of this is that the compressed air/fuel mixture has more room to travel without stalling on engine components thereby improving combustion.

Figure 14 illustrates a modified piston in operation. The flat landing area is indicated by 144. A hollowed recess (dotted) allows clearance for the fuel injector 142. Radical fuel spray 140 is forced outward by the raised centre section 141.

A further variation is shown in figure 13. A piston 130 with a raised centre 131 travels toward a cylinder head incorporating a recessed combustion chamber 132. The inlet and outlet valves are schematically represented by 134 and 135 respectively. This embodiment is suitable for operation in low pressure turbo or non-turbo configurations.

At the top of its travel, the annular landing area is separated from a corresponding dimensioned surface on the cylinder head by a narrow gap.

This particular embodiment is advantageous in that the compressed heated gases do not come into excessive contact with engine components while retaining the even expansion of the air fuel mixture as described above.

The raised centre sections of the piston top surfaces may be integrally formed or attached securely by means known in the art. A two piece articulated piston is shown in figure 5. In this embodiment, the top member is slightly movable with respect to the skirt 52. At the position where the angle between the piston arm and the longitudinal axis of the piston is at its maximum, the force is transmitted via the skirt rather than the piston head 51. This reduces ring wear as the radially asymmetric forces on the sides of the top member of the piston are greatly reduced.

Where in the foregoing description reference has been made to integers or components having known equivalents then such equivalents are herein incorporated as if individually set forth.

Although the invention has been described by way of example and with reference to possible embodiments thereof, it is to be appreciated that improvements and/or modifications may be made thereto without departing from the scope and spirit of the appended claims.

Claims:

1. A reciprocating piston type internal combustion engine including supercharging and turbocharging means, the engine being adapted so as to reduce its compression ratio and increase drive to the supercharger and/or turbo charger.

2. An engine as claimed in claim 1 wherein the reduction in compression ratio in each cylinder is effected by varying the timing of one or more inlet valves, more preferably by closing the one or more inlet valves prior to the end of the induction stroke of the cylinder.

3. A reciprocating piston type internal combustion engine incorporating boosted induction.

4. An engine as claimed in claim 3 wherein the boosted induction is effected by means of supercharging and/or turbocharging means.

5. A method of varying valve timing in a reciprocating piston type internal combustion engine including early opening of one or more exhaust valves and/or late closure of one or more inlet valves and/or the closure of one or more inlet valves prior to the end of each induction stroke.

6. A method of varying valve timing as claimed in claim 5 wherein the closure of the one or more inlet valves prior to the end of the induction stroke occurs in conjunction with a reduction in compression ratio of the engine and/or in conjunction with boosted induction.

7. A method of varying valve timing as claimed in either claim 5 or 6 further comprising closing one or more inlet valves substantially at bottom dead centre of piston travel on crankshaft rotation.

8. A method of varying valve timing as claimed in any one of claims 5 to 7 wherein the closure of the one or more inlet valves occurs up to 15 degrees of crank rotation after bottom dead centre or more preferably at or before bottom dead centre.

9. A method of varying valve timing as claimed in any one of claims 5 to 8 wherein the inlet and exhaust valves action have little or no overlap, more preferably the exhaust valve(s) open at approximately 50 degrees before bottom dead centre.

10. A method of varying valve timing as claimed in any one of claims 5 to 9 further comprising delaying the closure of the one or more inlet valves until after the compression stroke starts.

11. A method of varying valve timing as claimed in any one of claims 5 to 10 wherein delaying of the closure of the one or more inlet valves after the compression stroke starts occurs at higher engine speeds.

12. A variable timing wheel for a valve operating camshaft wherein the camshaft is driven by a variable timing, compound wheel.

13. A variable timing wheel as claimed in claim 12 wherein the compound wheel comprises:

a hub section located on the axis of a camshaft;

a rotational drive means capable of transmitting rotational movement to the hub section about it's axis;

a first actuation means, wherein the hub section, drive means and actuation means are coaxial and are adapted so that when the actuation means is displaced along the axis, the hub section and rotational drive means rotate relative to one another around their common axis.

14. A variable timing wheel as claimed in claim 13 wherein the hub section comprises a drive shaft which protrudes from the axis of the camshaft and has a male meshing means adapted to mesh with a complementary female meshing means in the first actuation means, and where the rotational drive means comprises a drive wheel adapted to mesh with the exterior of the first actuation means wherein when the first actuation means is axially displaced the hub section and the rotational drive means are rotationally displaced with respect to one another.

15. A variable timing wheel as claimed in either claim 13 or 14 wherein the meshing means comprise angled splines or slots which react and mesh with pins or recesses.

16. A variable timing wheel as claimed in any one of claims 13 to 15 wherein the first actuation means is displaced axially by hydraulic, electronic or mechanical means.

17. A variable timing wheel as claimed in any one of claims 13 to 16 wherein the first actuation means comprises a cylinder body which incorporates meshing means on its outer surface and a female axial meshing recess at one or both ends.

18. A variable timing wheel as claimed in any one of claims 13 to 17 wherein the rotational drive means is constrained so as not to be capable of axial movement.

19. A variable timing wheel as claimed in any one of claims 13 to 18 wherein the first actuation means is controlled by an engine management system, a speed and/or load sensitive governor or directly by an operator.

20. A piston for a compression ignition engine comprising:

a cylindrical member having a central axis and a top surface or crown comprising a convex surface which is adapted so that upon fuel injection and subsequent compression of an air/fuel mixture, the air/fuel mixture is forced radially outward from the axis of the cylindrical member.

21. A piston as claimed in claim 20 wherein the top surface comprises a substantially convex conical surface which is symmetrical about the axis of the cylindrical member and where the conical shape extends radially to the edge of the top surface.

22. A piston as claimed in either claim 20 or 21 wherein the substantially convex conical surface extends partially radially outwards so that a substantially flat annular portion is formed in the top surface between the edge of the convex conical surface and the edge of the cylindrical member.

23. A cylinder head, in which a cylindrical member as claimed in any one of claims 20 to 22 moves, and is adapted so that at the top of the compression stroke, the area between the cylinder head surface and the substantially flat annular surface surrounding

the convex surface is of negligible volume, thereby expelling substantially all of the air between the aforesaid surfaces at the top of the compression stroke.

24. A piston as claimed in any one of claims 20 to 22 used in conjunction with boosted induction.

25. A cylinder head as claimed in claim 23 used in conjunction with low or no boosted induction.

26. A piston as claimed in any one of claims 20 to 22 used according to the method of claims 5 to 11.

27. A cylinder head as claimed in either claim 23 or 25 used according to the method of claims 5 to 11.

28. An engine as claimed in any one of claims 1 to 4 including a variable timing wheel as claimed in any one of claims 12 to 17.

29. An engine as claimed in any one of claims 1 to 4 operating according to the method of any one of claims 5 to 11.

30. An method of valve timing substantially as described herein and with reference to any of the drawings.

31. A variable timing wheel substantially as described herein and with reference to any of the drawings.

32. A cylinder substantially as described herein and with reference to the drawings.

33. A cylinder head substantially as described herein and with reference to the drawings.

34. An engine substantially as described herein and with reference to any of the drawings.

AMENDED CLAIMS

[received by the International Bureau on 25 March 1996 (25.03.96); original claims 1-34 replaced by amended claims 1-27 (5 pages)]

1. A four cycle compression ignition engine optionally including supercharging and/or turbo charging means, the engine being adapted to reduce its geometrical compression ratio, said engine incorporating one or more pistons each comprising:

a cylindrical member having a central axis and top surface in the form of a convex surface adapted so that upon fuel injection and subsequent compression of an air/fuel mixture, the air/fuel mixture is forced radially outward from the axis of the cylindrical member.

2. An engine as claimed in claim 1 wherein the top surface of each cylindrical member comprises a substantially convex conical surface which is symmetrical about the axis of the cylindrical member and where the conical shape extends partially radially outwards so that a substantially flat annular portion is formed in the top surface between the edge of the convex conical surface and the edge of the cylindrical member.

3. An engine as claimed in either one of claims 1 or 2 wherein the cylindrical member is adapted so that at the top of the compression stroke, the area between a cylinder head surface and the substantially flat annular surface surrounding the convex surface is of negligible volume, thereby expelling substantially all of the air between the aforesaid surfaces at the top of the compression stroke.

4. An engine as claimed in either one of claims 1 or 2 incorporating a flat combustion chamber roof.

5. An engine as claimed in any one of claims 1 to 4 wherein the cylinder compression is controlled by means of valve timing, said valve timing adapted so that excess intake air is bled off by delaying the exhaust valve(s) closure until the piston has completed the first part of its induction stroke in such a manner as to cause at least some of the intake air to pass into the exhaust system when the engine has the inlet valve open.

6. An engine as claimed in any one of claims 1 to 4 in which cylinder compression is controlled by early closing of the inlet valve(s).

7. An engine as claimed in any one of claims 1 to 4 wherein each combustion chamber has a centrally placed fuel injector nozzle.

8. A compound variable timing wheel comprising:

a hub section located on the axis of a cam shaft;

a rotational drive means capable of transmitting rotational movement to the hub section about is axis;

a first actuation means; and wherein the hub section, drive means and actuation means are coaxial and are adapted so that when the first actuation means is displaced along the axis, the hub section and rotational drive means rotate relative to one another around their common axes.

9. A compound variable timing wheel as claimed in claim 8 wherein the hub section comprises a drive shaft which protrudes from the axis of the camshaft and has a male meshing means adapted to mesh with a complementary female meshing means in the first

actuation means, and where the rotational drive means comprises a drive wheel adapted to mesh with the exterior of the first actuation means wherein when the first actuation means is axially displaced from the hub section and the rotational drive means are rotationally displaced with respect to one another.

10. A compound variable timing wheel as claimed in either claim 8 or 9 wherein the meshing means comprise angled splines or slots which react and mesh with pins or recesses.

11. A compound variable timing wheel as claimed in any one of claims 8 to 10 wherein the first actuation means is displaced axially by hydraulic, electronic or mechanical means.

12. A compound variable timing wheel as claimed in any one of claims 8 to 11 wherein the first actuation means comprises a cylindrical body which incorporates meshing means on its outer surface and a female axial meshing recess at one or both ends.

13. A compound variable timing wheel as claimed in any one of claims 8 to 12 wherein the rotational drive means is constrained so as not to be capable of axial movement.

14. A compound variable timing wheel as claimed in any one of claims 8 to 13 wherein the first actuation means is controlled by an engine management system, a speed and/or load sensitive governor or directly by an operator.

15. An engine as claimed in any one of the preceding claims 1 to 7 wherein the top surface of each cylindrical member is relieved so as to provide clearance for valves that are operating when the cylindrical member is at the top of its travel.

16. An engine as claimed in any one of claims 1 to 7 and 15 wherein the top surface of each cylindrical member comprises of substantially convex conical surface which is symmetrical about the axis of the cylindrical member and where the conical shape extends radially to the edge of the top surface.

17. An engine as claimed in any one of claims 1 to 7 and 15 and 16 wherein the top surface of each cylindrical member is adapted so that the centre of the top surface will be located substantially immediately below the injector when the cylindrical member is at the end of its compression stroke and the top surface section from the centre to edge is concave and the edge of the top surface is lower than that top surface at the centre of the cylindrical member.

18. An engine as claimed in any one of claims 7 and 15 to 17 wherein each cylindrical member is relieved so as to accommodate off axis or centrally located injectors.

19. An engine as claimed in any one of claims 7 and 15 to 18 wherein the fuel injector spray angle is adapted so as to direct the fuel spray plume substantially clear of the cylinder head and the cylindrical member top surface.

20. An engine as claimed in any one of claims 1 to 7 and 17 to 18 having valve timing controlled by a compound variable timing wheel as claimed in any one of claims 8 to 15.

21. An engine as claimed in any one of claims 1 to 7 and 15 to 20 wherein the cylindrical member is articulated.

22. A method of operating an engine comprising:

opening exhaust valve(s) early so as to evacuate hot exhaust gasses from a cylinder while the power stroke is only partially complete, where a turbo charger is used to recover substantially all of the lost exhaust energy;

using pre-compressed intake air to drive the piston down on its induction thereby creating a secondary power stroke through the induction cycle; and

moderating the compression cycle pressure by closing the inlet valve(s) before the end of the induction stroke.

23. An method of valve timing substantially as described herein and with reference to any of the drawings.

24. A variable timing wheel substantially as described herein and with reference to any of the drawings.

25. A piston substantially as herein described with reference to the drawings.

26. A cylinder head substantially as described herein and with reference to the drawings.

27. An engine as substantially as desribed herein and with reference to any of the drawings.

ASPEC57039

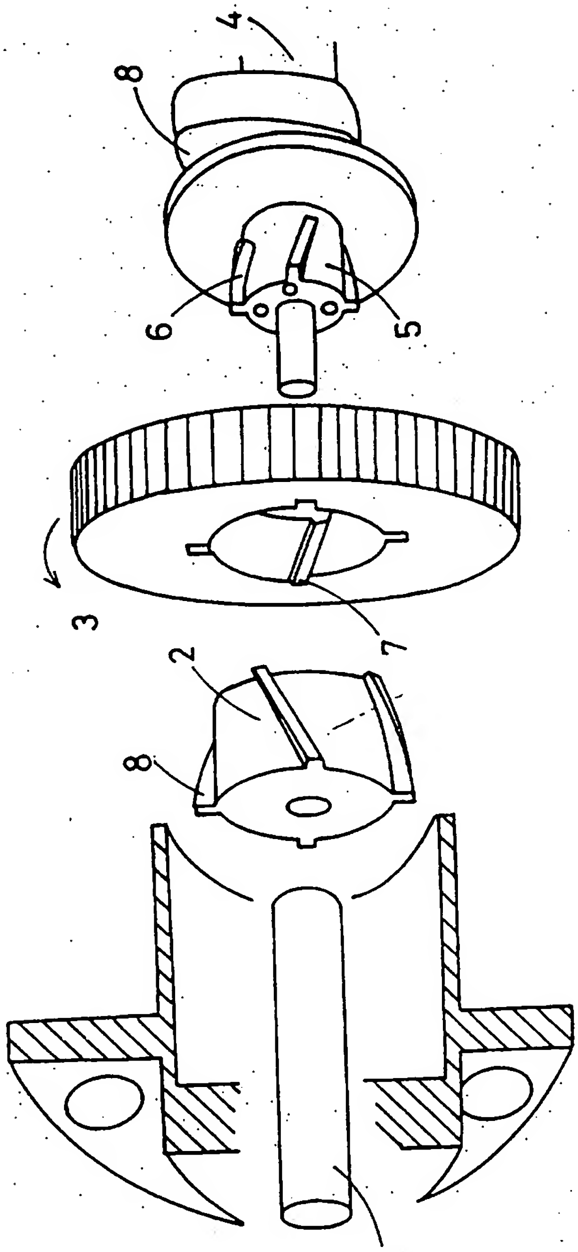

FIG.1

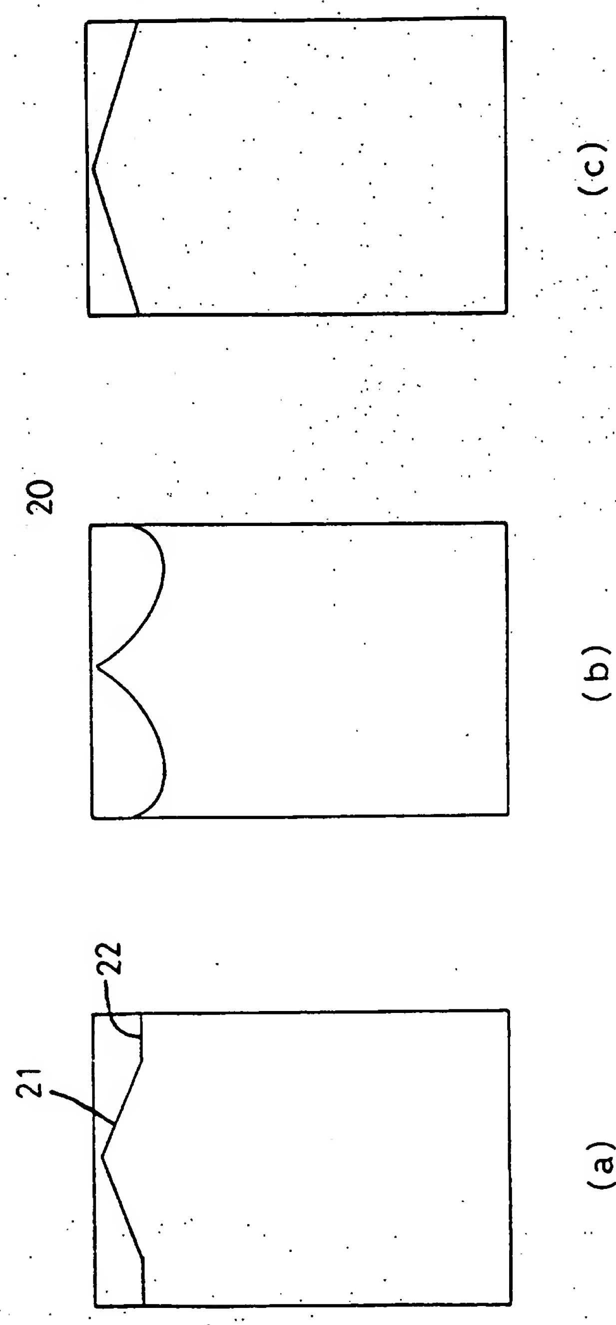

FIG.2

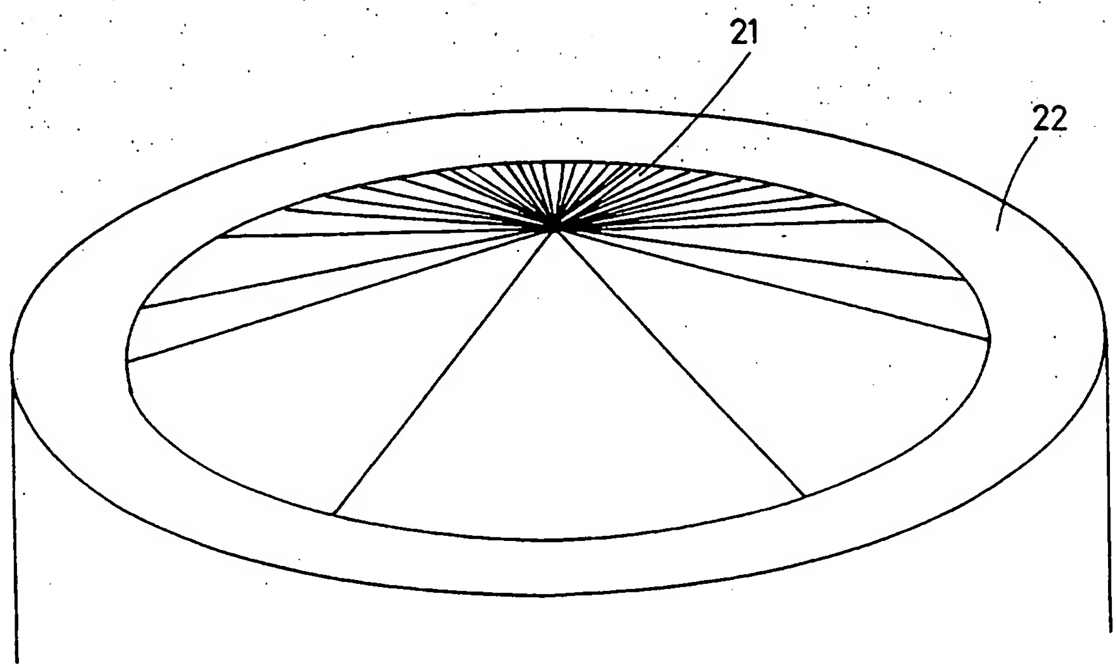

FIG.3

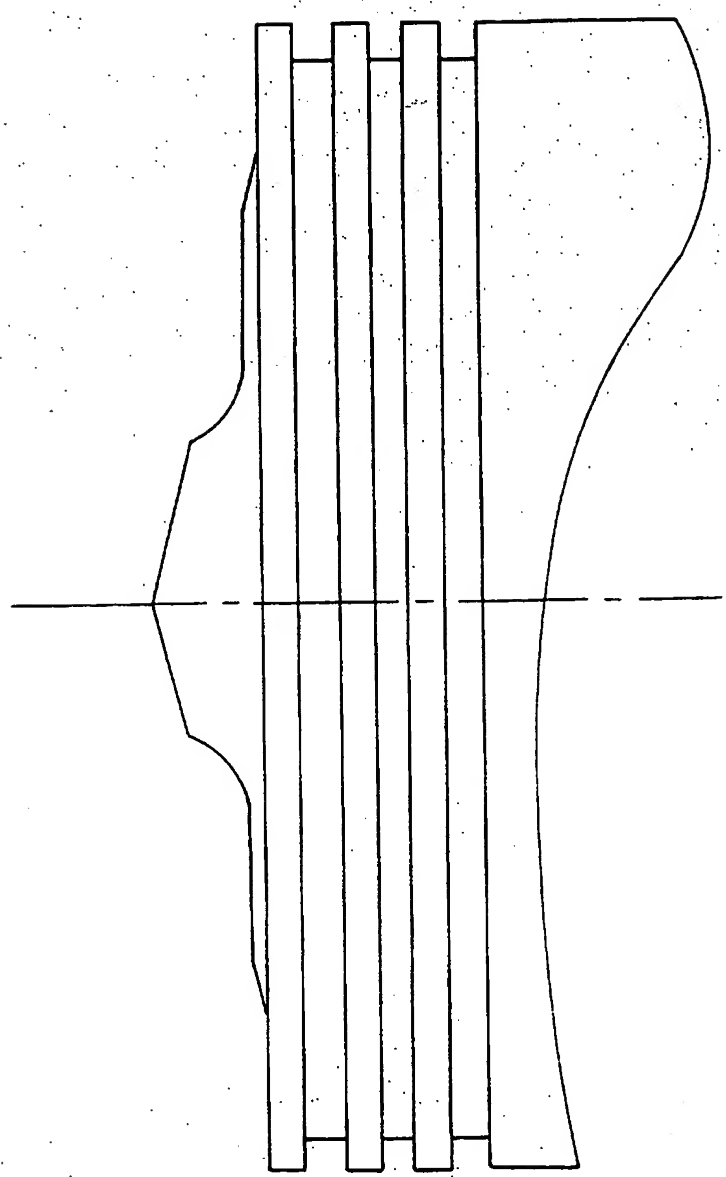

FIG.4

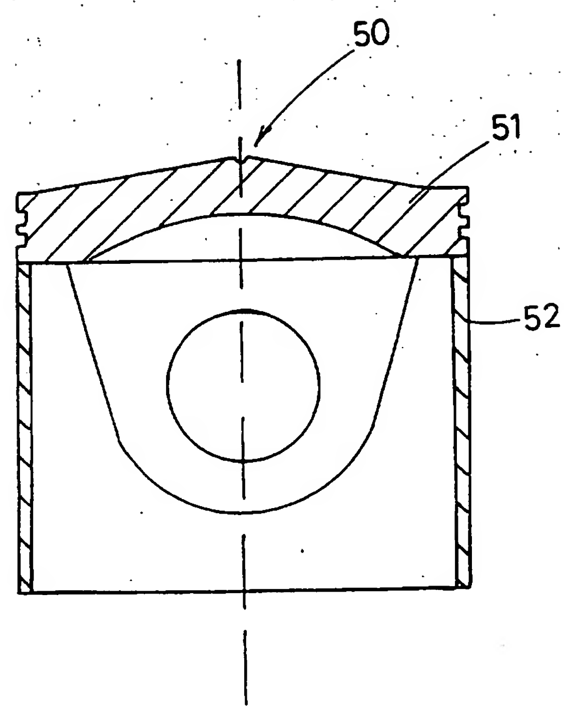

FIG.5

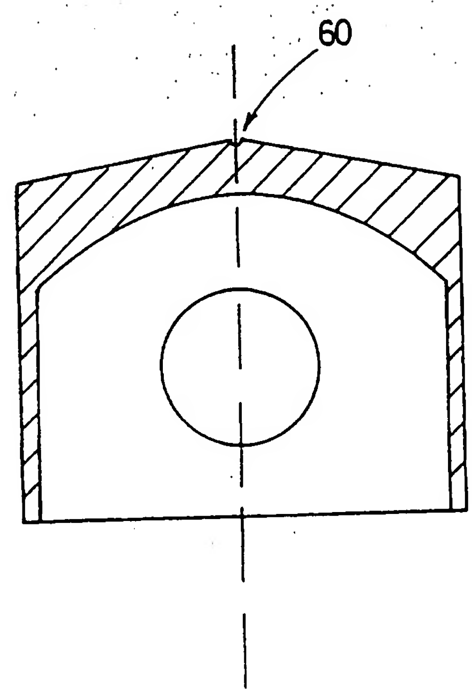

FIG. 6

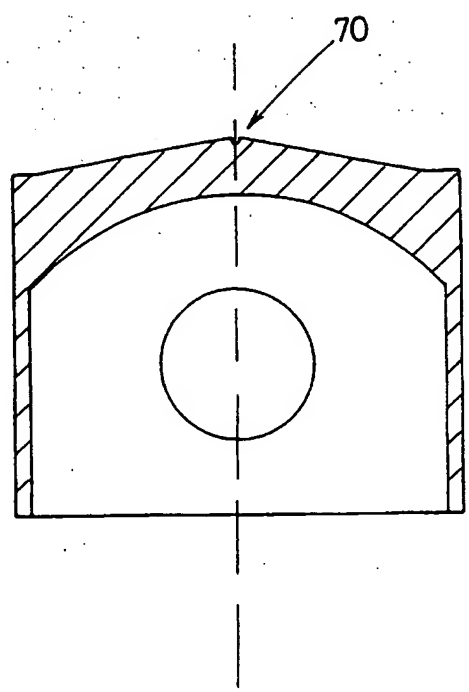

FIG. 7

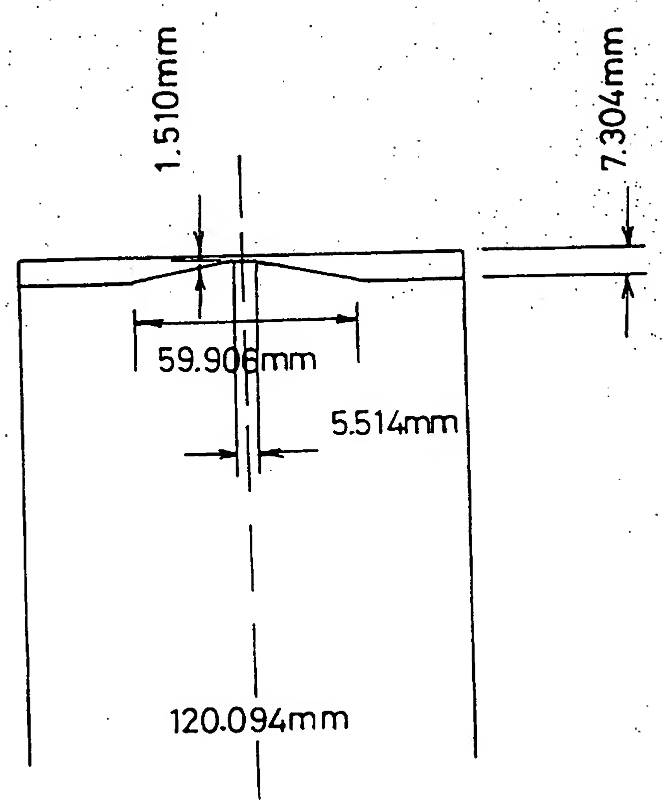

FIG. 8

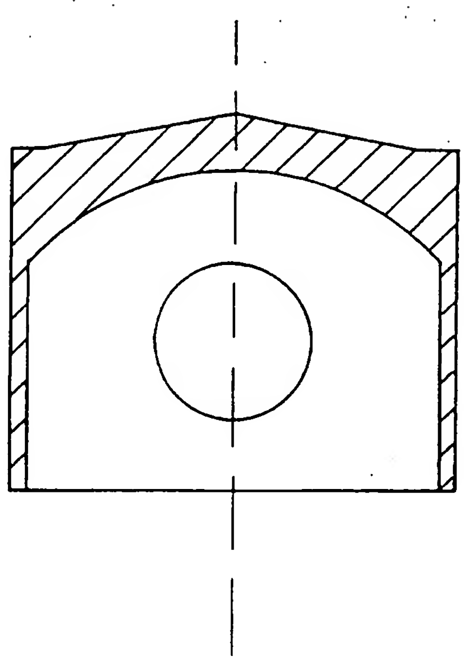

FIG. 9

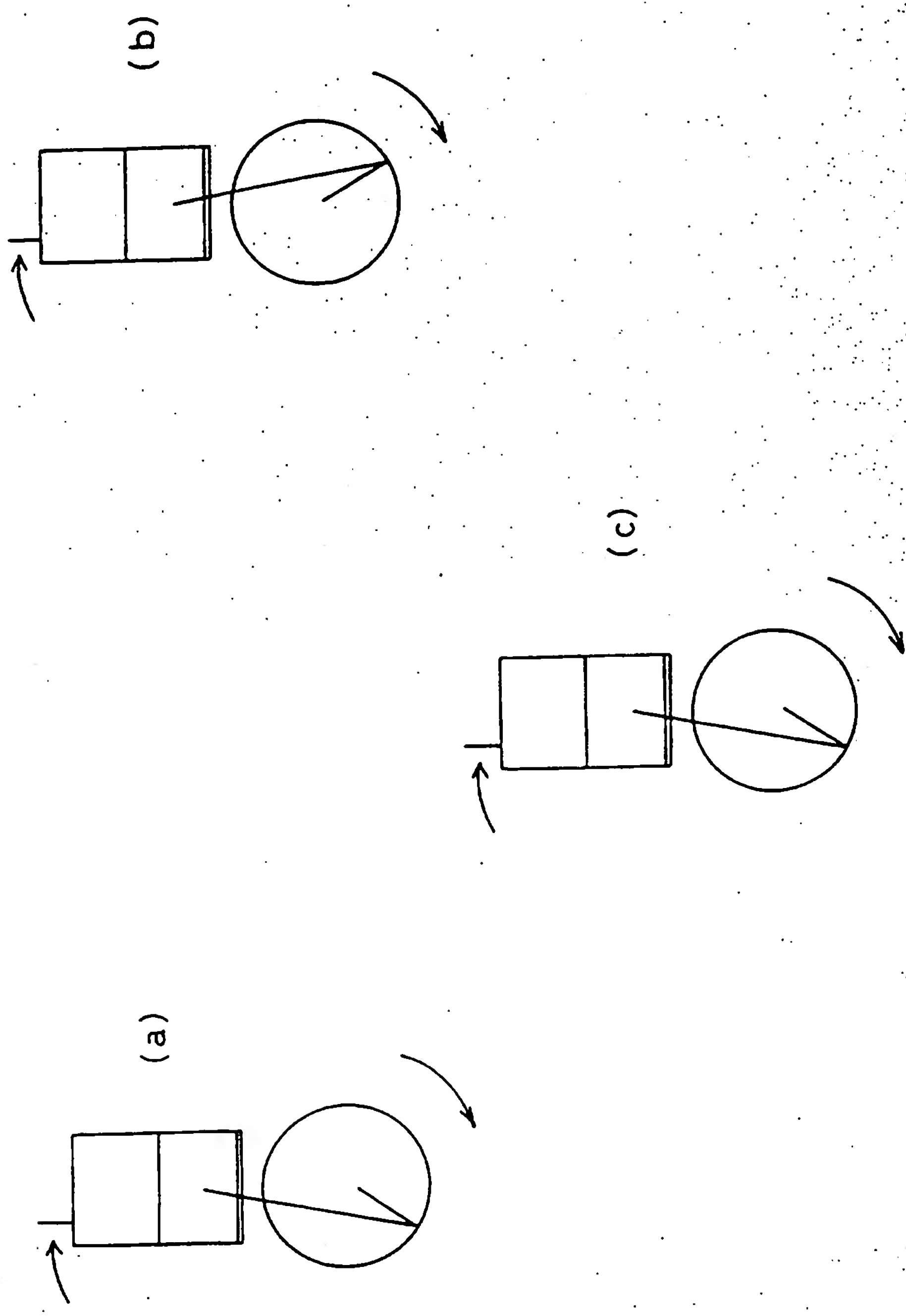

FIG.10

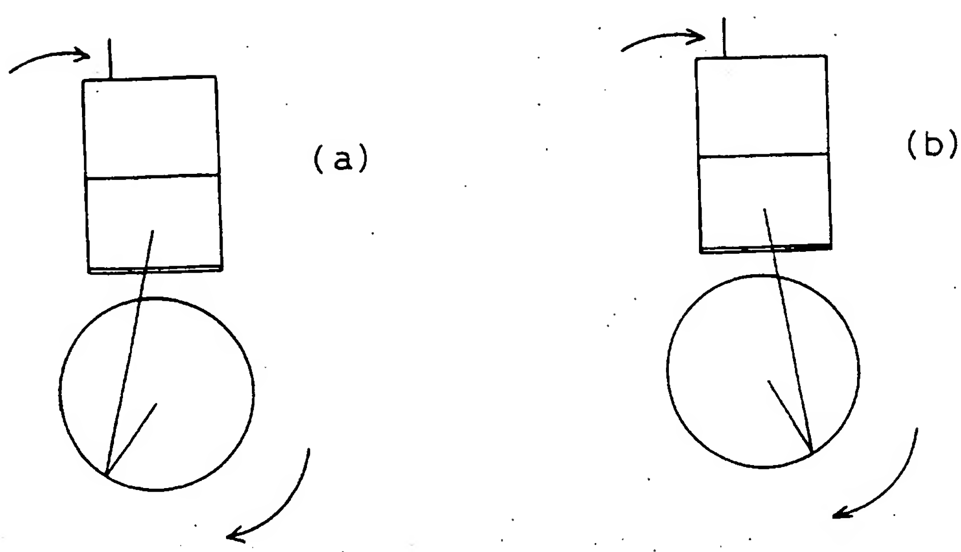

FIG.11

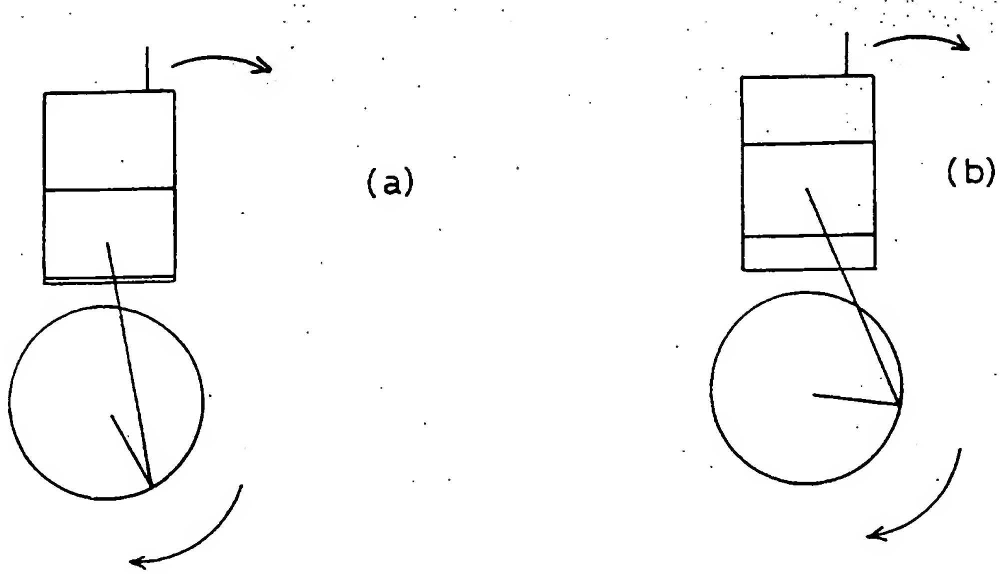

FIG.12

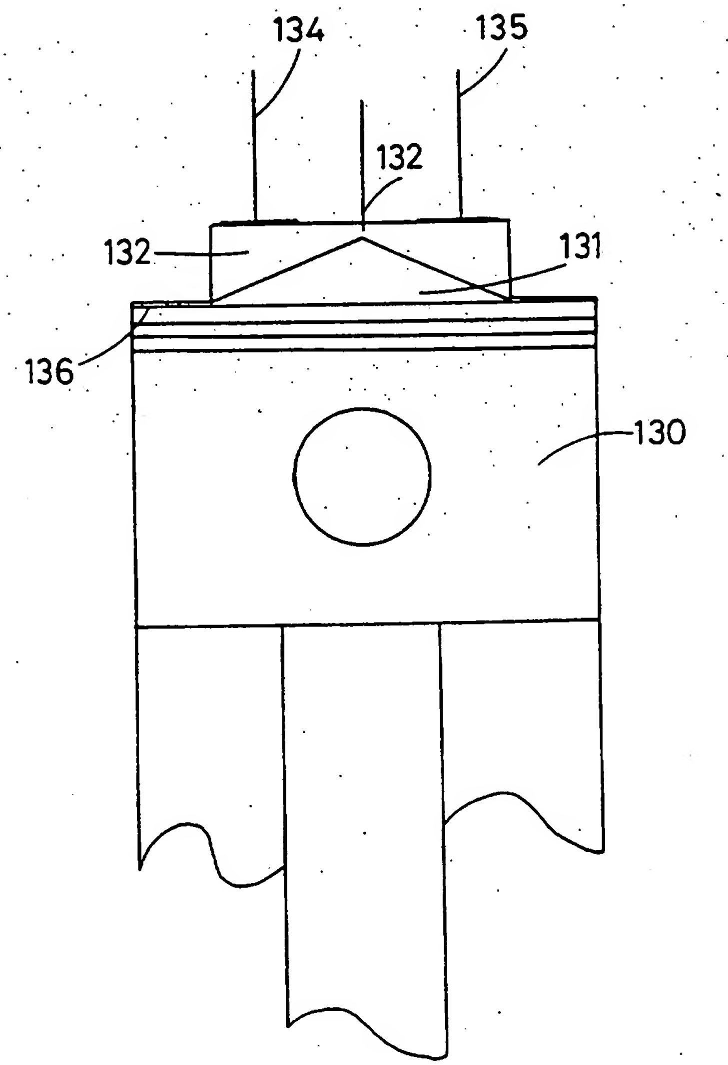

FIG.13

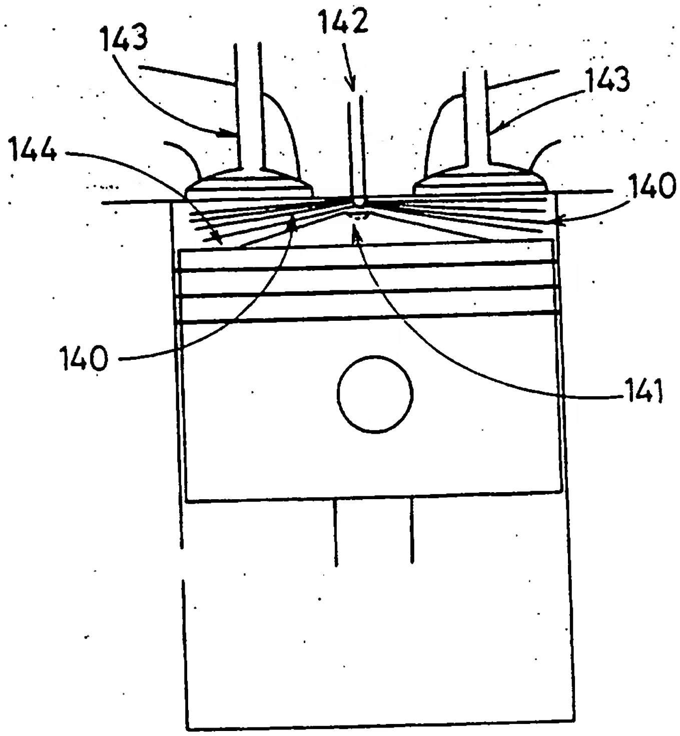

FIG.14

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/NZ 95/00104

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl^{6}: F02B 41/02, 41/00, F01L 1/344, F02F 3/24, 3/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : F02B 41/00, 41/02, 41/04, F02D 15/00, F01L 1/344, 1/34, F02F 3/24, 3/28

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Derwent

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5255637 A (SCHECHTER) 26 October 1993 column 3 third and fourth paragraphs and lines 60-63	1-8, 10-11, 29
X	WO 92/04536 A (AB VOLVO PENTA et al) 19 March 1992 abstract	3-4
A	GB 2133467 A (SWANSON) 25 July 1984 page 1 lines 30-39	9

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 January 1996	02 FEB 1996

Name and mailing address of the ISA/AU
AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION
PO BOX 200
WODEN ACT 2606
AUSTRALIA Facsimile No.: (06) 285 3929

Authorized officer

JAGDISH BOKIL

Telephone No.: (06) 283 2371

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/NZ 95/00104

C (Continuation)	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	AU 61918/80 A (SOCIETE D'ETUDES DE MACHINES THERMIQUES S.E.M.T.) 5 March 1981 page 2 liine 21 - page 3 line 5, page 17 line 27 - page 18 line 7	3-5, 7-11, 29
X	US 2670595 A (MILLER) 2 March 1954 column 4, second complete paragraph	3-11, 29
X	AU 16502/53 (158214) B (MILLER) 7 May 1953 column 4 lines 3-30, column 7 lines 21-25	1-11, 29
X	Patent Abstracts of Japan, M 1608, page 150, JP 06-42316 A (NIPPON DENSO CO LTD) 15 February 1994 whole abstract	12-19, 28
X	US 5209194 A (ADACHI et al) 11 May 1993 figure 2	12-19, 28
X	US 5080052 A (HOTTA et al) 14 January 1992 figures 2, 5	12-19, 28
P,X	Patent Abstracts of Japan, JP 07-150950 A (HIROYASU et al) 13 June 1995 whole abstract	20, 23-25
X	DE 3728167 A (KRUPP MAK MASCHINENBAU GmbH) 9 March 1989 figures 1-2	20, 23-25
X	Derwent Abstract Accession No. 86-117958/18, Class Q52, SU 1183698 A (TURBOMOTOR-NYIZAVOD) 7 October 1985 whole abstract	20, 23-25
X	Patent Abstracts of Japan, M 169, page 159, 57-126541 (MITSUBISHI JUKOGYO KK) 6 August 1982 whole abstract	20, 23-25
X	FR 1479937 A (BLACKSTONE & CO LTD) 5 May 1967 figures	20-25
X	DE 569702 A (LANOVA Ag) 7 February 1933 figure 1	20-25

Box II continued

(a) Claims 1-2, 28-29 are directed to an engine characterized by a simultaneous reduction in the compression ratio and increase in boost pressure.

(b) Claims 3-4 are directed to an engine with boosted induction.

(c) Claims 5-11 are directed to a method of varying valve timing in an engine (thereby varying the compression ratio) but not being limited to the feature of simultaneously changing the boost pressure.

(d) Claims 12-19 are directed to a variable timing wheel characterized by its constructional features.

(e) Claims 20-25 are directed to a piston or a cylinder head and characterized by the feature of piston crown shape.

Since the above-mentioned groups of claims do not share any of the technical features identified as underlined, a "technical relationship" between the inventions, as defined in PCT rule 13.2 does not exist. Accordingly the international application does not relate to one invention or to a single inventive concept.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No.
PCT/NZ 95/00104

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	5255637	EP	568214				
WO	9204536	AU SE	84907/91 9002849	BR	9106815	EP	547111
GB	2133467	DE	3401295	FR	2539454	JP	59138709
AU	8061918	BR ES FR PL	8005437 494651 2464372 226506	DK ES JP SE	3700/80 8200742 56050231 8005910	EP FI NO YU	24994 802683 802537 2172/80
US	5209194	JP	5263614				
US	5080052	DE	4108111	JP	3286104		
DE	3728167						

END OF ANNEX